

PROCESS FOR DECONTAMINATING AN ENCLOSED SPACE

5 Background of the Invention:

Field of the Invention:

10 This invention relates to the decontamination of enclosed
spaces, the surfaces defining these spaces, and the surfaces
of objects within these spaces by removing therefrom chemical
or microbiological contaminants such as air pollutants,
pesticides, drugs of abuse, bacteria, fungi, and viruses.

15 Each year, especially during the winter months, many thousands
of people suffer from infections commonly known as gripe,
flu, and influenza. The infective microorganisms believed to
be responsible pass from an infected person to others,
particularly in crowded locations.

20 As a public health measure, it is therefore considered
desirable to reduce the number of infective microorganisms in
enclosed spaces.

25 Fumigation to diminish the number of infective microorganisms
in enclosed spaces intended to be used by a large number of
people or inhabited by farm animals has long been practiced.

A variety of gaseous and liquid agents have been used,

including inorganics such as chlorine, chlorine dioxide, hydrogen peroxide, iodine, ozone, and permanganate salts, and numerous organic antimicrobials.

5 Chemical contaminants have been mitigated by various techniques adapted to the particular contaminant, including electrostatic precipitation, mechanical displacement by high-pressure steam and other gases under pressure, neutralization by appropriate reagents, and washing of surfaces with any of a host of cleansing formulations.

10
11
12
13
14
15
16
17
18
19
20 All of these methods are subject to significant physical limitations. Gaseous treating agents are subject to the difficulty of providing sufficient mass of active agent to be effective, since in any given volume the mass of gaseous agent cannot be greater than that determined by the ideal gas law $PV = nRT$, P being pressure, V volume, n the number of moles i.e. the mass, R the gas constant, and T the temperature in K. Condensed phase agents such as liquids, on the other hand, must overcome gravity to reach all parts of an enclosed space including obstructed areas before eventually settling to the lowest level.

Individual disclosures in this field include the following:

Lembke, U.S. Patent No. 6,224,827 B1 of May 1, 2001 disclosed a water-free alcohol disinfectant capable of destroying spores, preferably including 0.5-3 % by weight hydrogen peroxide for use in industrial context for bacteriological
5 cleaning of surfaces.

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Belfer, U.S. Patent No. 6,106,854 of August 22, 2000 disclosed an asepsis disinfectant composition in liquid form including an anti-infective germicidal and antiseptic agent selected from the group consisting of hydrogen peroxide, urea hydrogen peroxide and betaine hydrochloride; a sanitizer and bactericide selected from the group consisting of iodine, iodine pentafluoride, iodine monobromide, iodine chloride, iodine halides, iodophors and tetraglycine hydroperiodide; a cleansing agent, an antioxidant and stabilizing agent, a pH adjuster, and a diluent. The composition may also include a gas propellant for acting as a carrier in order to provide a pressurized aerosol spray.

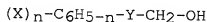
20 Childers. U.S. Patent No. 5,906,794 of May 25, 1999 disclosed a continuous operation closed loop system for conducting closed loop flow through vapor phase decontamination. In the optimized method, a flow of carrier gas is recirculated in a closed loop conduit circuit that leads into, through, and out
25 of a sealable chamber. A liquid decontaminant is vaporized and delivered into the carrier gas flow entering the chamber, and

then converted to a form suitable for disposal after exiting the chamber. The liquid decontaminant preferably comprises aqueous hydrogen peroxide. The system includes a liquid sterilant vaporizer unit for delivering a vaporized liquid
5 sterilant into the carrier gas. Liquid sterilant is preferably atomized in an atomizer fluidly connected to the vaporizer, and is delivered to the vaporizer in the form of a fine mist to increase the likelihood of complete vaporization.

10 Childers, U.S. Patent No. 5,492,672 of February 20, 1996 disclosed a method for sterilizing items using a multi-component vapor phase sterilant where one component is water. The method includes injecting sterilant vapor into a chamber at subatmospheric pressure controlled at various levels at
15 various times, discontinuing the flow of sterilant vapor into, through, and out of the chamber to hold the sterilant vapor therein for a period of time sufficient to permit the sterilant vapor to permeate the chamber and come into effective contact with items to be sterilized, and repeating
20 the steps of flowing sterilant and discontinuing the flow of sterilant in alternating fashion until sterilization of goods in the chamber is achieved. The sterilizer in which the method is practiced includes a sterilization chamber, a source of liquid sterilant, a vacuum pump, a vaporization chamber
25 upstream from the sterilization chamber, and a system of valves. The pump draws the liquid sterilant from its source

through a filter and on to the inlet of the vaporization chamber. Air is drawn through a filter and into the inlet of the vaporization chamber. A flow restrictor (venturi) is provided in-line, upstream of the inlet so that the air or the air and sterilant mixture passes through the flow restrictor to the inlet of the vaporization chamber.

Hool, U.S. Patent No. 3,982,022 of Sept. 21, 1976 disclosed a composition for the control of microorganisms containing a combination of active substances consisting of a first compound halogen substituted 2-phenoxyphenol and a second compound of the formula



wherein n represents 0 or a whole number from 1 to 5, X represents a halogen atom, and Y represents a radical of the formula -O-CH₂- or -CH₂- or the direct bond,

together with the usual carriers and/or dispersing agents.

Mullen, U.S. Patent No. 3,635,836 of January 18, 1972 disclosed thickened viscous or gelled acid dispersions comprising a selected protic acid and particulate proteinaceous material derived from legume seeds or cottonseeds. The dispersions are useful for applying strongly

acid films to surfaces of metal, stone, ceramic, textile or wooden articles for the purpose of treating the surface. Once the treatment has been completed the dispersions can be washed off. The composition of the thickened dispersions comprises
5 by weight of the total composition about 1.5 to 20.0 percent particulate proteinaceous material, about 20.0 to 55.0 percent protic acid, and about 40.0 to 75.0 percent water, alkanol, or alkylcarbonyl compounds. Useful alkanols are mono- and polyhydroxy alcohols preferably containing 10 or fewer carbon atoms, and their cyclic or branched counterparts such as cyclohexanol.

Summary of the Invention:

It is accordingly an object of the invention to provide a process for decontaminating an enclosed space that overcomes the above-mentioned disadvantages of the prior art devices and methods of this general type, in which a contaminated enclosed space as well as the surfaces defining the space and the surfaces of any objects within the space is decontaminated by
20 treatment with liquid particles of controlled dimensions containing a contaminant neutralizing agent and able to reach all parts of the space and remain suspended therein for hours.

It is a further object of the invention to return the treated
25 enclosed space to access and practical use in a simple manner.

With the foregoing and other objects in view, there is provided, in accordance with the invention, a process for decontaminating an enclosed space containing a contaminant and surfaces surrounding the space, which comprises the steps of

5

providing a liquid contaminant neutralizing agent having a predetermined surface tension and viscosity,

providing a source of carrier gas under a first pressure,

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

providing a source of carrier gas under a second pressure greater than the first pressure,

25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

injecting the liquid contaminant neutralizing agent into a nozzle with carrier gas under the first pressure, thereby generating a loaded stream of contaminant neutralizing agent and carrier gas,

41

injecting a stream of carrier gas under the second pressure and the loaded stream into a venturi generator nozzle, thereby mixing the streams and generating a stream comprising carrier gas and particles of contaminant neutralizing agent having a predetermined particle size distribution,

42

injecting the stream comprising carrier gas and the particles of contaminant neutralizing agent into the enclosed space,

causing particles of contaminant neutralizing agent to dwell in the enclosed space for a predetermined time, thereby decontaminating the enclosed space,

5

and removing particles of contaminant neutralizing agent from the treated enclosed space.

10 With the foregoing and other objects in view, there is also
11 provided, in accordance with the invention, a process as above
12 which further comprises reducing the flow of the loaded stream
13 subsequent to the dwell time of contaminant neutralizing agent
14 in the enclosed space. The flow of the loaded stream can be
15 reduced to a slower rate or to a rate of zero, so that the
16 flow of loaded stream is stopped entirely.

17 The process of the invention can be followed by injection of
18 pure carrier gas into the enclosed space subsequent to the
19 dwell time of contaminant neutralizing agent therein. Such
20 injection of pure carrier gas serves to displace from the
21 enclosed space the spent contaminant neutralizing agent
22 solution and conversion products resulting from its use,
23 thereby facilitating access to and use of the decontaminated
24 enclosed space.

25

It is a feature of the invention that particles of contaminant neutralizing agent generated according to the invention can remain suspended in the enclosed space for at least one hour. This assures effective contact of the contaminant neutralizing agent with contaminant to be treated at any place throughout the enclosed space, including surfaces defining the space as well as objects located therein. As a result, irregularly shaped spaces as well as spaces including irregularly shaped objects are effectively treated. As a further result, the process can be applied to relatively large spaces having volumes of at least one cubic meter and ranging up to several thousand cubic meters.

The predetermined viscosity of the liquid contaminant neutralizing agent according to the invention is in the range from 0.15 to 1500 centipoises measured at 20°C, preferably from 0.164 to 1499 centipoises so measured.

The predetermined surface tension of the liquid contaminant neutralizing agent according to the invention is in the range from 10 to 100 dyn/cm measured against air or liquid vapor at 20°C, preferably from 17.0 to 72.5 dyn/cm so measured.

The predetermined particle size distribution according to the invention is such that at least 90% of the particles of liquid contaminant neutralizing agent are in the range from 1

micron (μm) to 100 microns in diameter in a Gaussian distribution, and preferably at least 95% of the particles of liquid contaminant neutralizing agent are in the range from 8 micron to 55 micron according to Gaussian distribution.

5

The liquid contaminant neutralizing agent according to the invention can be a liquid substance having the desired effectiveness in neutralizing a contaminant as well as the predetermined properties of viscosity and surface tension.

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211

shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims.

5

The construction and method of operation of the invention, however, together with additional objects and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

Other features which are considered as characteristic for the invention are set forth in the appended claims.

Although the invention is illustrated and described herein as embodied in a process for decontaminating an enclosed space, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims.

The construction and method of operation of the invention, however, together with additional objects and advantages thereof will be best understood from the following description

of specific embodiments when read in connection with the accompanying drawings.

Brief Description of the Drawing:

- 5 The single figure is a circuit loop diagram illustrating the flow of contaminant neutralizing agent solution and carrier gas through a venturi generator in which particles of predetermined particle size distribution are generated and injected into the enclosed space to be decontaminated.

Description of the Preferred Embodiments:

10 The liquid contaminant neutralizing agent can comprise any substance effective in neutralizing a contaminant of concern. The agent is selected primarily for maximal effectiveness and
15 secondarily for the ability to avoid or minimize undesirable effects such as toxicity to humans, corrosivity to the surfaces of the space to be decontaminated, difficulties in removing the agent from the treated space after use, and
20 pollution of the environment after removal from the treated space.

Subject to these considerations, non-limiting neutralizing agents for contaminants having acid properties and contaminants readily hydrolyzed to acidic substances are
25 alkalis such as borax, ethanolamine, potassium bicarbonate, potassium carbonate, potassium hydroxide, sodium carbonate,

sodium hydroxide, tetrapotassium pyrophosphate, triethanolamine and trisodium phosphate. Especially potassium hydroxide: water: ethanol=1:1:1. Such alkalies are effective neutralizing agents for acidic contaminants such as phosgene, 5 diisopropyl phosphorofluoridate and certain halogenated pesticides.

Similarly, neutralizing agents for other chemical contaminants are selected on the basis of known principles of chemical reactivity and solubilization. 10

Subject to the above considerations, non-limiting neutralizing agents for microbiological contaminants such as live bacteria, bacterial spores, fungi and viruses can be any agent known to be effective against the organism of concern. A plurality of effective agents can be used, especially for purposes of preventive prophylaxis. 15

Preferred contaminant neutralizing agents include organic halogen compounds such as hexachlorocyclohexane and aldehydes such as formaldehyde, 2-ethylhexan-1-al, and pentane-1,5-dial. 20

A particularly preferred contaminant neutralizing agent for microbiological contaminants is 2-phenylethanol. This alcohol unites high antimicrobial effectiveness with low toxicity 25

(oral LD₅₀ in rats = 1790 mg/kg), agreeable odor properties and substantial absence of side effects.

When the contaminant neutralizing agent comprises a solvent,
5 the solvent can be aqueous or non-aqueous, as required by the solubility properties of the substance having the desired effectiveness in neutralizing a contaminant. Where practical the solvent comprises water. Frequently the solvent also comprises a water soluble organic liquid to enhance the solubility of the effective substance. Suitable water soluble organic liquids able to solubilize many effective substances include acetone; aliphatic alcohols having 1 to 4 carbon atoms such as methanol, ethanol, 1-propanol, 2-propanol, 1-butanol, 2-butanol, 2-methyl-1-propanol and 2-methyl-2-propanol; 10 dimethyl sulfoxide; and ether alcohols having 1-2 ether groups and 1-2 hydroxyl groups such as diethylene glycol, 2-methoxyethanol, 2-ethoxyethanol, and 2-(2'-butoxyethoxy)ethanol. Mixtures of such liquids can be used if desired, with the relative proportions of the components such
20 that solubility in the mixture of the effective substance and water if present is assured.

The effective substance can be present in the liquid contaminant neutralizing agent in any convenient concentration
25 consistent with the predetermined surface tension and viscosity. Typical concentrations of effective substance are

in the range from 0.5% to 20% by weight, preferably 1% to 10% by weight.

10 The surface tension of the liquid contaminant neutralizing
5 agent is primarily a function of the nature and concentration
of the effective substance and the solvent. When necessary, a
surfactant is included to diminish the surface tension. The
nature of the surfactant is not critical. Anionic, cationic,
nonionic, and zwitterionic surfactants can be used. Within
each of these categories a plentiful selection is commercially
available. For a convenient compilation of surfactants within
each of the named categories reference can be had to Trinh et
al., U.S. Patent No. 5,540,853, column 7 line 5 to column 14
line 4, here incorporated by reference.

15 As is well known in the art, surfactants vary in their
tendency to cause foaming. Low foam surfactants are available
and are particularly preferred.

20 The viscosity of the liquid contaminant neutralizing agent is
primarily a function of the nature and concentration of the
effective substance and the solvent and may be influenced by
surfactant when present. These can be judiciously selected to
achieve the predetermined viscosity. Secondary adjustments of
25 viscosity can be accomplished by modest additions of organic

liquids having a large viscosity depressing effect per unit weight; a preferred viscosity depressant is 1-butanol.

The nature of the carrier gas is not critical. Any non-
5 corrosive gas can be used. Air is preferred for reasons of convenience and cost.

Referring now to the figure of the drawing, a loaded stream of liquid contaminant neutralizing agent under gas with a first pressure is conveyed into a venturi generator, nozzle or flow restrictor 2 and is there mixed with a stream 3 of carrier gas under a second pressure greater than the first pressure. The interaction of the streams 1 and 3 in the flow restrictor 2 results in great turbulence, intensive mixing, and expulsion of a stream of particles 4 of liquid contaminant neutralizing agent having a predetermined particle size distribution through a connecting line into the enclosed space to be treated (not shown).

20 If desired, the stream of particles 4 can be accompanied or followed by a gas stream, preferably a stream of air, 5, issuing from an optional variable speed blower 6. The blower speed is regulated as a function of the power supply to help in adjusting the concentration of liquid contaminant
25 neutralizing agent in the stream of particles 4.

The loaded stream 1 is generated by mixing liquid contaminant neutralizing agent from a storage container 10 supplied from a feed vessel 9 with carrier gas under a first pressure 11, and passes through a valve 12 to the flow restrictor 2. Deposition of oversize particles only takes place on the two rotating plates 13, 14 for the purpose of draining the remaining liquid.

Carrier gas is delivered from a pressurized gas supply point 15. Multiple pressurized gas supply points can be used if available. From a single pressurized gas supply point, a stream of gas is split by passing through two pressure regulator valves 16 and 17 to provide stream 11 at a first pressure and stream 3 at a second pressure greater than the first pressure. The stream 11 of carrier gas at the first pressure pumps the liquid contaminant neutralizing agent before passing through valve 12 to the nozzle 2, while the stream 3 of carrier gas at the second pressure passes directly into the flow restrictor 2.

The first pressure is preferably in the range of 0.02 to 0.5 bar. The second, greater pressure, is less than or equal to 10 bar, preferably in the range of 1 to 10 bar.

It can be seen that the process of the invention provides several parameters that can be set so as to achieve a narrow

particle size distribution of contaminant neutralizing agent in the enclosed space able to remain suspended and in contact with all interior surfaces so as to accomplish effective neutralization of contaminant therein. These parameters are the viscosity and surface tension of the liquid contaminant neutralizing agent, the gas pressure at the constriction of the venturi generator, the carrier gas flow rate and the configuration of the venturi generator. Since each of these parameters is amenable to independent control, a great variety of settings is available to enable effective neutralization of contaminants in the enclosed space to be treated.

The flow restriction applied by the venturi generator can be constant as a result of the construction of the device, or can vary with time as a result of the operation of moving parts therein. An example of venturi generator with moving parts includes two circular disks with holes or slots in parallel planes rotating at different speeds. As the disks rotate, both in the same direction or in opposite directions, the incoming stream is constricted to varying extent as the openings in the disks are alternately reinforced and blocked.

A venturi generator suitable for the practice of this invention is commercially available as „Venturigenerator Typ VII“ from Chemlab GmbH, A-3032 Eichgraben, Austria.

The following Examples are provided to further illustrate the operation of the process of the invention without limiting its scope, which is defined by the appended claims.

5 EXAMPLE 1: Disinfection of a school ventilating unit with built-in humidification

The purpose of this example was the removal of streptococci and pneumococci pathogenic to humans and removal of legionellae if present.

The volume of the ventilating unit was approximately 120 m³

Apparatus settings

Carrier air speed 20 m³/min.

Venturi ratio 1: 940

Feed rate of the disinfectant solution 240 ml/min.

Properties of the disinfectant solution:

20 Viscosity: $48 \cdot 10^{-3}$ Pa·s (48 centipoises) adjusted with n-Butanol

Surface tension: 22.5 dyn/cm adjusted with 10% DBS (dodecylbenzenesulfonic acid) Na salt in distilled water.

Disinfectant composition: 58.5% by weight distilled water
40% wt. 1-propanol
1.5% 2-phenylethanol

- 5 The progress of disinfection was followed by determining the total number of germs as the average of 12 individual measurements.

Procedure

The venturi generator was connected to a view opening in the ventilating unit, normally kept closed except when used for cleaning, using a flexible hose of ID 100mm.

The total number of microorganisms measured before treatment was greater than 10^6 per square centimetre, including such species as *Streptococcus aureus*, *Aspergillus niger*, *Geotrichum candidum*, *Penicillium commune* and *Candida albicans*.

- 20 Precisely controlled venturi particles of disinfectant were blown in for 10 minutes while maintaining the specified apparatus parameter.

- The disinfectant particles were allowed to act for one hour
25 without any air blow, followed by 10 minutes of blowing ordinary air through the treated space.

Result of treatment.

After treatment no microorganism growth was detected.

5 Specifically, no Legionellae were detected.

As a test for possible activity against Anthrax, the treatment was repeated with a special disinfecting solution and test culture of *cereus subtilis* inserted into the ventilating unit, measuring 147-238 microorganisms per plate. After the treatment, a total of 1-3 microorganisms per plate was found.

Thus the total number of germs was reduced by 99.2% (average of 12 experiments).

EXAMPLE 2: Disinfection of a stable in a swine feeding establishment.

Purpose: decontamination of pathogenic viruses microorganisms.

20

Volume of the stable approximately 7000 m³

Carrier air speed 250 m³/min.

Venturi ratio 1: 920

25 Feed rate of the disinfectant solution 420 ml/min.

Properties of the disinfectant solution:

Viscosity: $42 \cdot 10^{-3}$ Pa.s (42 centipoises) adjusted with n-Butanol

Surface tension: 22.7 dyn/cm adjusted with 10% DBS

5 (dodecylbenzenesulfonic acid) Na salt in distilled water.

Disinfectant composition: Chemlab Clean Air Type XI - a disinfectant commercially available from Chemlab GmbH, A-3032 Eichgraben, Austria.

Procedure:

The venturi generator was connected to an air vent in the stable through a flexible hose of ID 100mm. All animals were removed from the stable and the doors and windows closed.

5 The total number of microorganisms measured before treatment was greater than 10^6 per square centimetre, including microorganisms like *Aspergillus niger*, *Candida albicans*, *Clostridium tetani*, *Corynebacterium renale*, and *Nocardia asteroides*.

20 Precisely controlled venturi particles of disinfectant were blown in for 1 hour while maintaining the specified apparatus parameters.

25

The disinfectant particles were allowed to act for one hour without any air blow, followed by 2 hours of blowing ordinary air through the treated space with one door open.

5 Result:

No pathogenic microorganisms could be detected at 20 measuring points in the stable.

In a control test with *cereus subtilis* and a special disinfection liquid, ten test cultures were distributed throughout the space, diluted to 121-209 microorganisms per plate. After treatment, 1-3 microorganisms per plate were found, representing 99.3% reduction (average of 10 experiments) of the total number.

It should be noted that *cereus subtilis* is a very resistant anaerobic microorganism used having closely related properties to Anthrax (*bacillae anthracis*) where safety considerations prohibit experimentation with the latter.

20

Additional applications of the process of the invention include surface treatments such as the removal of rust particles from stainless steel structures such as long pipes and conduits, removal of fats and other organic air

25 contaminants from air in kitchens and eating places, as well

as removal of leaked and spilled chemical contaminants in workplaces.